AD-A060 805 WEAPONS SYSTEMS RESEARCH LAB ADELAIDE (AUSTRALIA) F/G 19/7
THE AERODYNAMIC DESIGN OF A ROCKET TEST VEHICLE FOR PHASE 2 OF --ETC(U)
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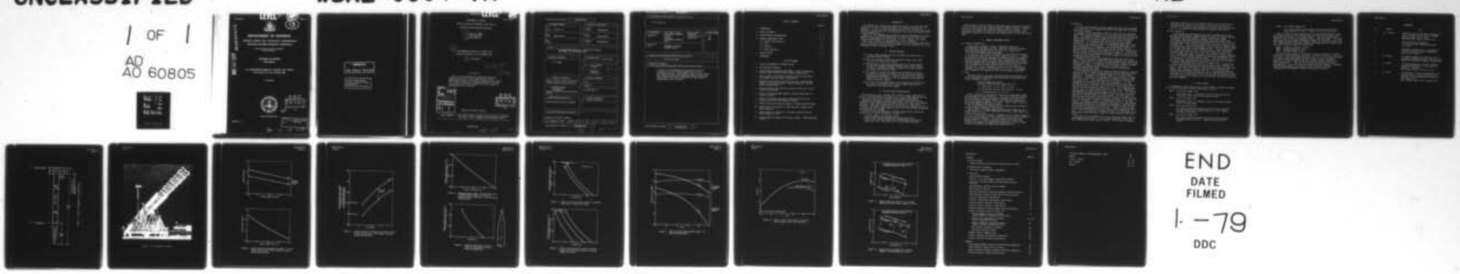

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TECHNICAL REPORT

WSRL-0004-TR

THE AERODYNAMIC DESIGN OF A ROCKET TEST VEHICLE FOR PHASE 2 OF THE AFSTAMS TASK

F.G. BURGER

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(9) TECHNICAL REPORT,

(14) WSRL-0004-TR

(6) THE AERODYNAMIC DESIGN OF A ROCKET TEST VEHICLE FOR PHASE 2 OF THE AFSTAMS TASK,

(10) F.G./Burger

(11) Apr 78

(12) 23p.

SUMMARY

Phase 2 of the AFSTAMS task required the practical demonstration of the falling sphere method of wind determination using a rigid 120 mm diameter passive sphere. This report describes the aerodynamic design of the free flight rocket test vehicle used to carry this sphere to approximately 20 km altitude.

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POSTAL ADDRESS: Chief Superintendent, Weapons Systems Research Laboratory Box 2151, G.P.O., Adelaide, South Australia, 5001.

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DOCUMENT CONTROL DATA SHEET

Security classification of this page: UNCLASSIFIED

1 DOCUMENT NUMBERS	
AR Number:	AR-001-174
Report Number:	WSRL-0004-TR
Other Numbers:	

2 SECURITY CLASSIFICATION	
a. Complete Document:	UNCLASSIFIED
b. Title in Isolation:	UNCLASSIFIED
c. Summary in Isolation:	UNCLASSIFIED

3 TITLE

THE AERODYNAMIC DESIGN OF A ROCKET TEST VEHICLE FOR PHASE 2 OF THE AFSTAMS TASK.

4 PERSONAL AUTHOR(S):

F.G. Burger

5 DOCUMENT DATE: April 1978

6 6.1 TOTAL NUMBER OF PAGES 22

6.2 NUMBER OF REFERENCES: 6

7 7.1 CORPORATE AUTHOR(S):

Weapons Systems Research Laboratory
Defence Research Centre Salisbury

7.2 DOCUMENT SERIES AND NUMBER

Weapons Systems Research Laboratory
0004-TR

8 REFERENCE NUMBERS

a. Task:

b. Sponsoring Agency:

9 COST CODE:

10 IMPRINT (Publishing organisation)

Defence Research Centre Salisbury

11 COMPUTER PROGRAM(S) (Title(s) and language(s))

12 RELEASE LIMITATIONS (of the document):

Approved for public release.

12.0	OVERSEAS	NO		P.R.	1	A		B		C		D		E	

Security classification of this page: UNCLASSIFIED

78 11 02 048

Security classification of this page: UNCLASSIFIED

13 ANNOUNCEMENT LIMITATIONS (of the information on these pages):

No limitation.

14 DESCRIPTORS:			15 COSATI CODES:
a. EJC Thesaurus Terms	Free flight rocket Aerodynamic estimates Rockets Missiles Aerodynamic stability Tests	Falling spheres Aerodynamic characteristics Projectiles	1907 2004
b. Non-Thesaurus Terms	Kookaburra launcher AFSTAMS vehicle		

16 LIBRARY LOCATION CODES (for libraries listed in the distribution):

SW SR SD AACA

17 SUMMARY OR ABSTRACT:
(if this is security classified, the announcement of this report will be similarly classified)

Phase 2 of the AFSTAMS task required the practical demonstration of the falling sphere method of wind determination using a rigid 120 mm diameter passive sphere. This report describes the aerodynamic design of the free flight rocket test vehicle used to carry this sphere to approximately 20 km altitude.

Security classification of this page: UNCLASSIFIED

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1. INTRODUCTION

The AFSTAMS task evolved from an Army requirement to up-grade the speed and accuracy of the "in-field" measurement of wind data for artillery purposes. Initially a study was made to determine the feasibility of using the falling sphere method of wind determination to obtain wind profiles below 20 km altitude(ref.1).

Phase 2 of this AFSTAMS task required the practical demonstration of this method using a rigid 120 mm diameter passive sphere ejected from a rocket vehicle at approximately 20 km altitude. For this purpose, five rocket vehicles were allocated for the appropriate trials at Woomera.

This report details the aerodynamic design of the free flight rocket test vehicle engineered to fulfil this requirement, and also summarises the vehicle performance results from these trials.

2. DESIGN PHILOSOPHY

(1) A single stage configuration was considered for simplicity in engineering detail design.

(2) Use of an existing rocket motor available at WSRL would reduce time and cost scales significantly.

(3) Aerodynamic and engineering design should be of similar format to that used on Upper Atmosphere Research (UAR) rocket vehicles for which a considerable amount of expertise has been obtained in Aeroballistics Division, WSRL.

(4) The sequence of events for sphere ejection should be similar in principle to that used successfully for the UAR falling sphere and dropsonde experiments. Hence the payload section should be separated from the boost motor on the trajectory up-leg and the sphere ejected near apogee.

(5) An initial target apogee height of 22 km should be considered for the vehicle to allow for loss of sphere apogee height due to separation of the head before apogee.

3. INITIAL DESIGN CONSIDERATIONS

The decision to use an existing "off the shelf" single stage motor to deliver a 120 mm diameter rigid sphere to 20 km altitude suggested the use of one of the family of the reliable 126 mm diameter Lupus motors.

Exploratory performance estimates indicated that the Lupus 3 motor (60.85 kN.s total impulse) and the Lupus 2D motor (48.1 kN.s total impulse) both had too much total impulse unless the vehicle was significantly ballasted. The Lupus 1A motor had just sufficient total impulse (37.8 kN.s) to achieve the initial target apogee height of 22 km if the vehicle drag and mass were kept to a minimum.

From this latter consideration to minimise drag and mass evolved the following basic vehicle configuration (figure 1):

4 calibre tangent ogive payload section
Lupus 1A motor with a "standard UAR" 152 mm long venturi
4 light alloy cruciform fixed fins of double-wedge cross-section
Launch mass of 36 - 38 kg (for an 85° launch elevation angle)

Restricting the maximum diameter of the head, which comprises the payload section, to that of the motor tube enabled the Kookaburra launcher (figure 2) to be used, which meant that launcher slippers were not required. This restriction in diameter did cause some structural design problems due to aerodynamic heating of the relatively thin fibreglass wall at the rear of the head.

4. GENERAL AERODYNAMIC DESIGN

4.1 General considerations

Rocket vehicle design is always a compromise between the interdependant requirements of drag, stability, structural rigidity, mass, and useful payload volume, and trade-offs between these conflicting requirements have to be made.

In this case, the initial body dimensions were fixed by the choice of the Lupus 1A motor and the 4 calibre tangent ogive nose. Although not necessarily being the planform for minimum fin drag, rectangular planform fins were chosen for their ease of manufacture and assembly. Experience gained from the design of Upper Atmosphere Research rocket vehicles suggested that the minimum fin panel size (for a 4 cruciform fin configuration) to reduce drag yet give sufficient vehicle stability for a vehicle estimated to weigh 38 kg at launch would be somewhere in the order of 152 mm chord x 115 mm span. Accordingly, these dimensions were adopted for the initial design calculations.

4.2 Drag

Resulting from the previously mentioned design considerations, the initial performance calculations were based upon the following body and fin parameters (figure 1):

4 calibre tangent ogive nose
rectangular planform double wedge fins with

(i) panel span = 115 mm, chord = 152 mm

(ii) leading and trailing edge thickness = 0.5 mm

(iii) thickness/chord ratio = 0.032

Further reduction of drag during the vehicle coasting phase could have been made by having a boattail. This, apart from the resultant stability penalty, would have entailed designing and testing a new venturi/fin mounting assembly which was not considered warranted for the limited number of vehicles to be used. Hence, it was decided to retain the standard UAR design of venturi.

The zero-incidence drag coefficients were obtained from reference 3 and DRCS computer program IG.2.44.1(ref.4).

Figure 3 gives the apogee height and maximum Mach number for the "clean" vehicle (i.e. no head separation) for vehicle launch masses of between 36 kg and 40 kg.

As can be seen from the general arrangement of the vehicle (figure 1), the tip of the fibreglass nose was slightly blunted to prevent melting due to aerodynamic heating. The small amount of spherical nose blunting ($^d/_D$ = 0.1) used had negligible drag effect, and in fact evidence now suggests that greater nose blunting up to $^d/_D$ = 0.3 may have been used without any appreciable penalty(ref.5,6).

4.3 Stability

In line with the general procedure adopted for UAR rockets designed in FR Group WSRL, the minimum static margin requirement was 10% of the body overall length.

The body and fin longitudinal stability coefficients for specified Mach numbers within the range 0 to 4.0 were obtained from references 2 and 3. The resultant vehicle centre of pressure positions are plotted versus Mach number in figure 4 together with the curve of required vehicle centre of gravity position to meet the 10% static margin requirement. It is apparent that the limiting centre of gravity position for this vehicle is that for maximum Mach number which occurs at the end of the thrusting phase. As the maximum Mach number for a given configuration is a function of the vehicle launch mass, the required vehicle centre of gravity position for 10% static margin can be derived directly in terms of the launch mass (figure 5). This can be further resolved into specifying the required centre of gravity position of the head for various values of head mass (figure 6) to assist in the mechanical design of the head.

Although at this stage, the designated fin panel size was 115 mm span x 152 mm chord with no sweep, the vehicle stability was checked for other fin panel shapes of similar area but different aspect ratio and/or leading edge sweep. No significant stability gain was made, and when considered in conjunction with the minor drag effects and the structural engineering aspects, very little would be achieved by changing from the basic shape.

As the mechanical design of the payload section progressed, it became evident that the 4 calibre tangent ogive nose did not allow sufficient space behind the rigid 120 mm diameter sphere for the head release mechanism. Consequently, the payload section was increased in length from 503 mm to 550 mm by the addition of a cylindrical section at the rear of the ogive. This extension had little effect on the vehicle performance, but did change the stability requirements. As were calculated for the 503 mm head, the required vehicle and head centre of gravity positions to meet the vehicle 10% static margin requirements were derived for head masses between 3 and 7 kg. It is apparent from figure 7 that for a head length of 550 mm, the stability requirements are impossible to meet for a head mass less than 4.5 kg. This section when manufactured and assembled weighed 5 kg and its centre of gravity position was 175 mm forward of its base datum. For this weight the centre of gravity position should be 290 mm forward of the datum, which for this type of payload would be difficult to achieve if the weight was not to be increased. Obviously increasing the weight to 6 kg would result in an acceptable centre of gravity position, but as the head had already been manufactured for laboratory environmental testing purposes, the alternative solution of increasing the fin span was chosen as the fins had not been manufactured at the time. Figure 8 shows the effect on the required head centre of gravity position of increasing the fin span. For a 5 kg head with its centre of gravity 175 mm forward of the head datum the fin panel span should be at least 130 mm for 10% static margin.

As several sets of Kookaburra Mk I first stage fins surplus from the UAR program were available, it was considered expedient to use those fins although their panel span was 152 mm. This of course involved a

performance penalty, but as the primary objectives of the task were to demonstrate the capability of ejecting a 120 mm diameter sphere at altitude and confirming radar discrimination between sphere and vehicle, the 2 to 3 km penalty in apogee height was considered justifiable.

4.4 Head separation

A requirement for head separation was that it should occur on the up-leg of the trajectory to allow sufficient separation distance between the head and the motor assembly at sphere ejection near apogee. Furthermore, Radar and Electronic Tracking Group advised that radar discrimination between the head and the motor assembly would be easier if the separation of the 2 objects occurred along the line of sight of the tracking radar. These two requirements can be achieved by ensuring that the vehicle flight path elevation angle coincides with the elevation angle of the radar (R1 Adour) at head separation time. Figure 9 shows that this coincidence occurs at +29 s (15.6 km altitude) for an 85° launch elevation angle (QE), and at +23 s (13.7 km altitude) for an 80° QE. From the performance aspect, the greater the altitude at which separation occurs, the smaller will be the drag rise (and hence performance loss) of the head due to its unstable mode of flight. This confirmed that the zero-wind launch elevation angle should be at least 85°, and consequently the nominal head separation time was chosen to be +30 s.

The head separation system relies on a volume of air, at ground level pressure, retained between the head and the forward end of the motor to eject the head away from the motor assembly when the shear pins have been broken - this system is similar to that used on the Kookaburra and Cockatoo upper atmosphere research vehicles. To assist the mechanical designers of this system, the effect of various separation velocities was investigated and a separation velocity of 10 m/s was determined as giving sufficient separation to prevent a collision between the decelerating motor and head assemblies.

5. TRIALS RESULTS

The performance results from the five rocket firings at Woomera for phase 1 of the AFSTAMS task may be briefly summarised as follows:

ADTV1 - fired 30th November 1976

Unsuccessfu trial - a structural failure of the rear end of the head occurred shortly after motor all-burnt.

ADTV2 - fired 24th August 1977

Unsuccessful trial - a premature release of the head occurred during the boost phase.

ADTV3 - fired 25th October 1977

This vehicle worked satisfactorily with the head containing the sphere achieving an apogee height of 17.4 km. (Sphere ejection did not occur.)

ADTV4 - fired 22nd November 1977

This vehicle worked satisfactorily with the head achieving an apogee height of 17.6 km. (Sphere ejection did not occur.)

ADTV5 - fired 23rd November 1977

This vehicle worked satisfactorily with the head achieving an apogee height of 17.6 km. (Sphere ejection did not occur.)

Figure 10 shows the radar trajectories of the head (containing the sphere) and the motor assembly of the vehicle ADTV3 plotted from the nominal head separation time of +30 s to just after apogee. These trajectories are very similar to those for the two subsequent vehicles ADTV4 and ADTV5. The actual head separation times cannot be confirmed, though the following comments from the R1 radar operators log sheets indicate that separation in all three cases must have occurred at about the correct time.

ADTV3 - "locked off (vehicle) at +35 s"
ADTV4 - "multiple echoes at +32 s"
ADTV5 - "multiple echoes at +35 s"

The actual apogee heights of the three 5 kg heads corrected to a vehicle launch mass of 36.3 kg(average launch mass of the three vehicles), are plotted in figure 11 together with the predicted values for a 36.3 kg launch mass for both nominal apogee performance and 95% of nominal apogee performance. Figure 12 is a similar plot for the motor assemblies also corrected to a 36.3 kg launch mass. These show an average over-estimation of apogee performance of 4.4% for the head and 2.4% for the motor assembly. Though no stability measurements were possible on these vehicles, the small discrepancies in performance indicate no instability problems.

REFERENCES

No.	Author	Title
1	S.G. Johnson	"Application of Falling Sphere Techniques to Artillery Meteorological System (AFSTAMS) Report on phase 1 of the Task". WRE-Report-1665 (WR&D), September 1976
2	-	"Engineering Design Handbook". U.S. Army Material Command AMCP706-280, July 1968
3	-	"Engineering Sciences Data - Aerodynamics sub-series (formerly Royal Aeronautical Society Data sheets)".
4	D.P. Brown	"A computer program to estimate the zero-incidence aerodynamic drag of rocket vehicles". WRE-Technical Note-1144 (WR&D), February 1974
5	L.C. Ward	"Force measurements at transonic speeds on axisymmetric forebodies to determine the effects of bluntness". RAE Technical Report 76088, July 1976
6	L.C. Ward	"Measurements of pressure distributions and pressure drags at zero incidence on both blunt and sharp axisymmetric forebodies at a Mach number of 3". RAE Technical Report 76160, November 1976

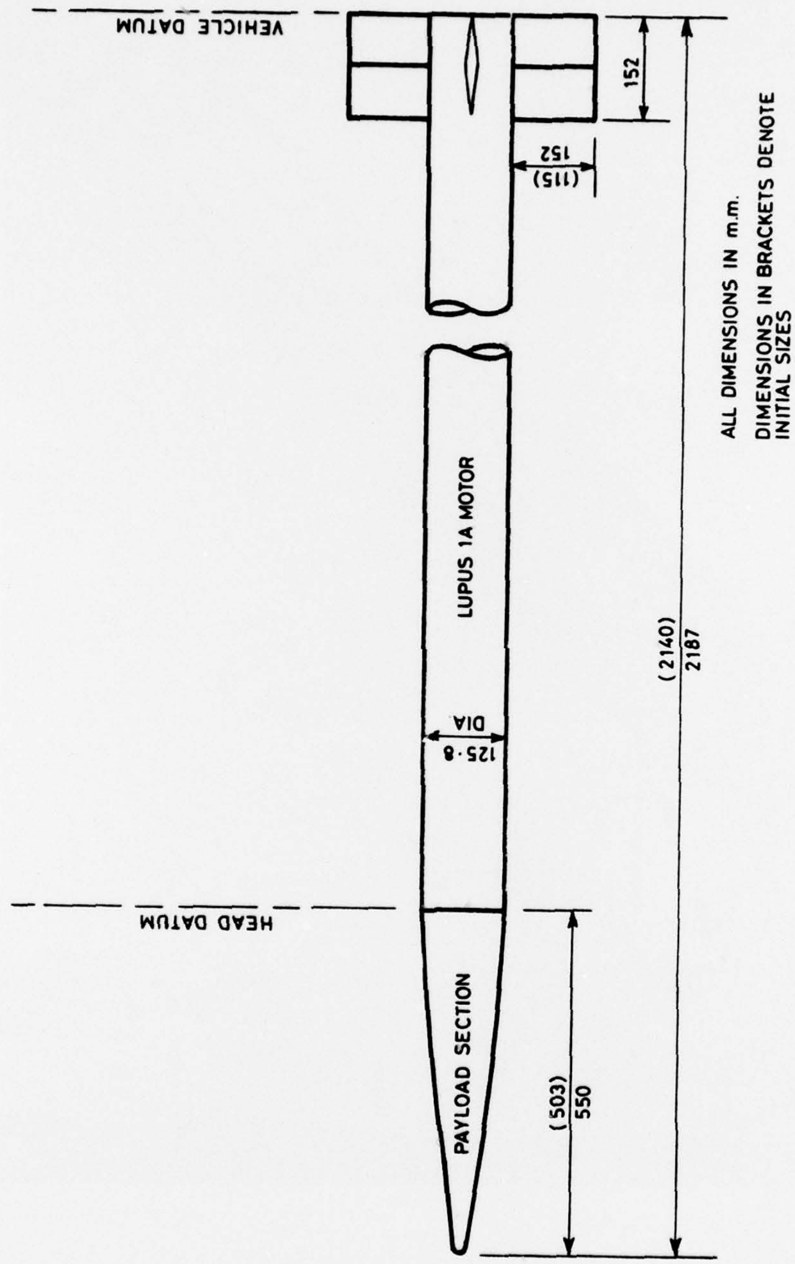

Figure 1. General arrangement of AFSTAMS vehicle

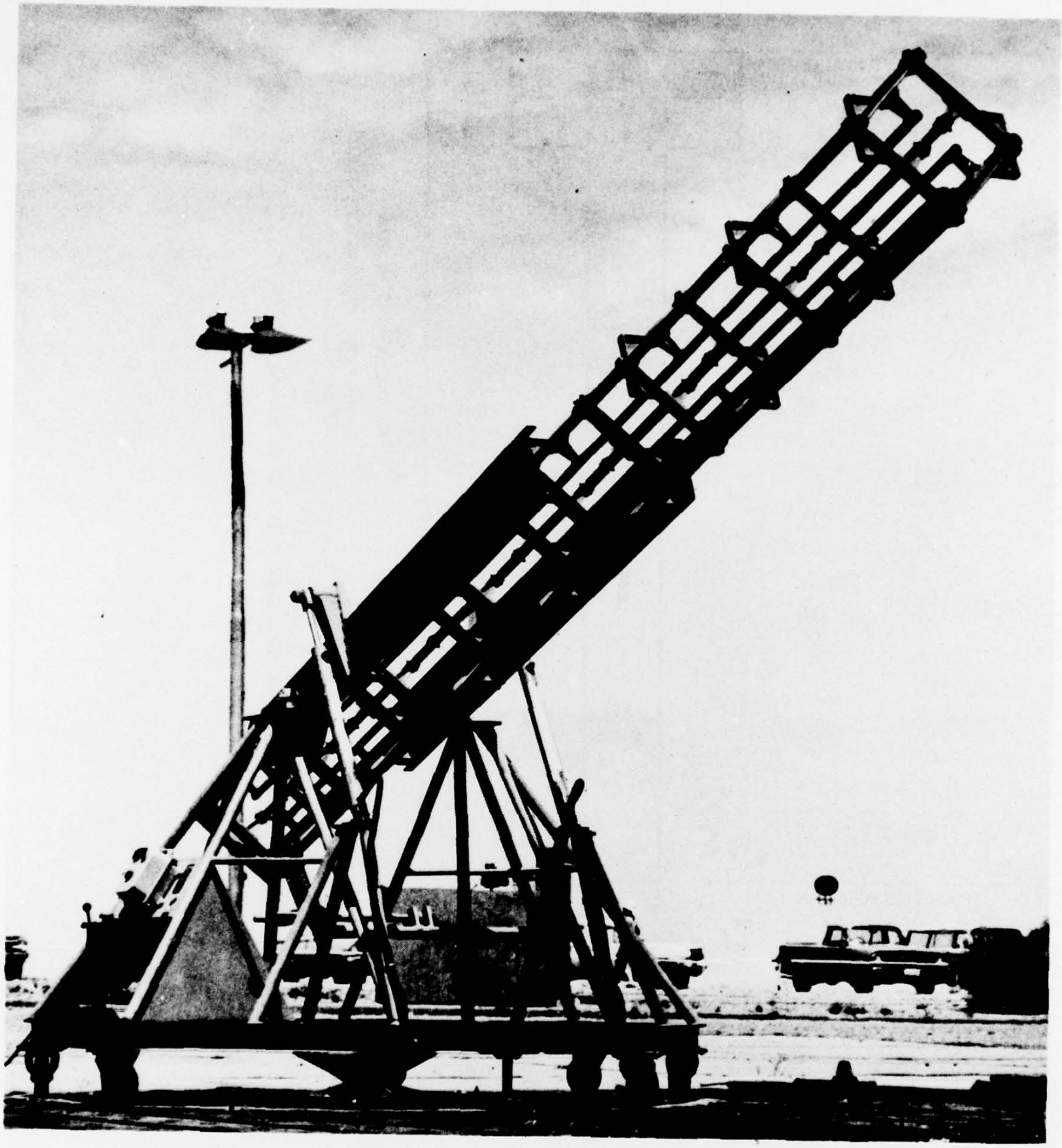

Figure 2. The Kookaburra Launcher

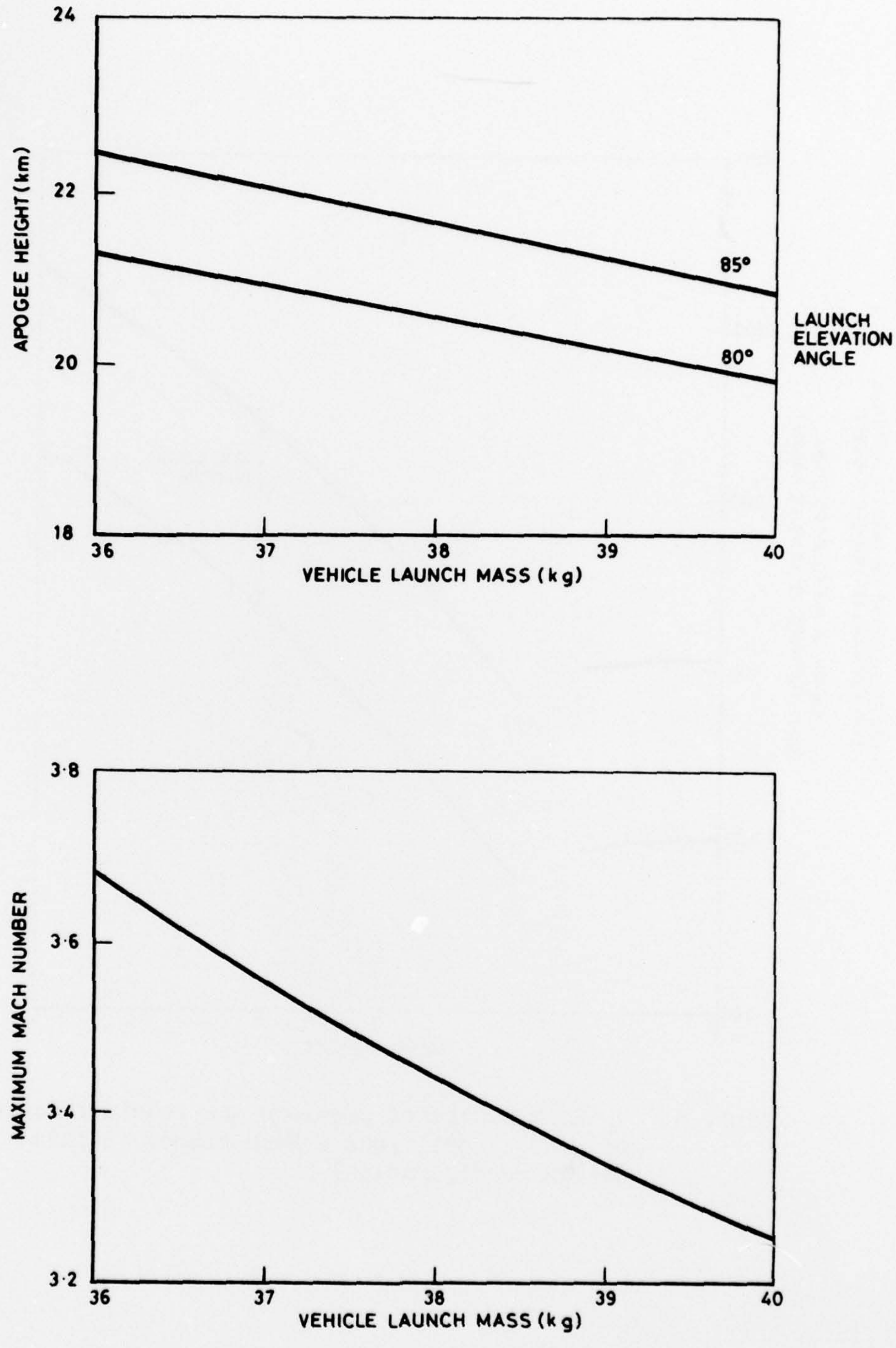

Figure 3. Apogee height and maximum Mach number v vehicle launch mass for the 'clean' vehicle (initial design configuration)

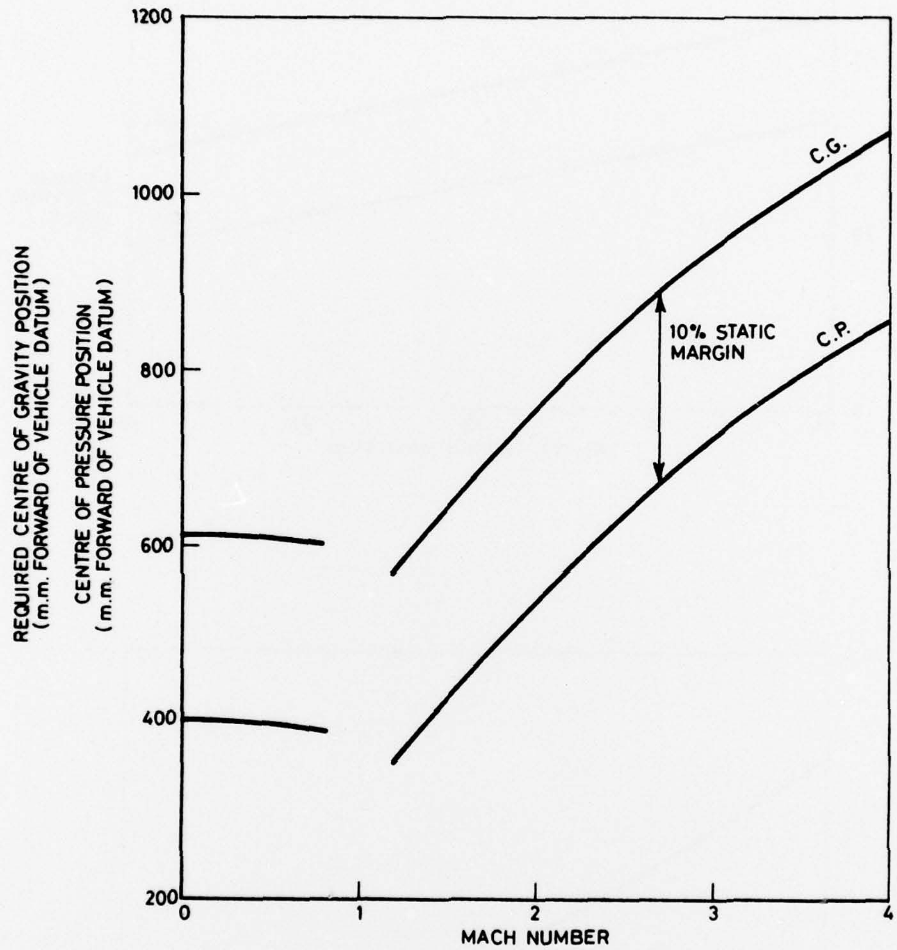

Figure 4. Vehicle centre of pressure and required centre of gravity positions v Mach number (initial design configuration)

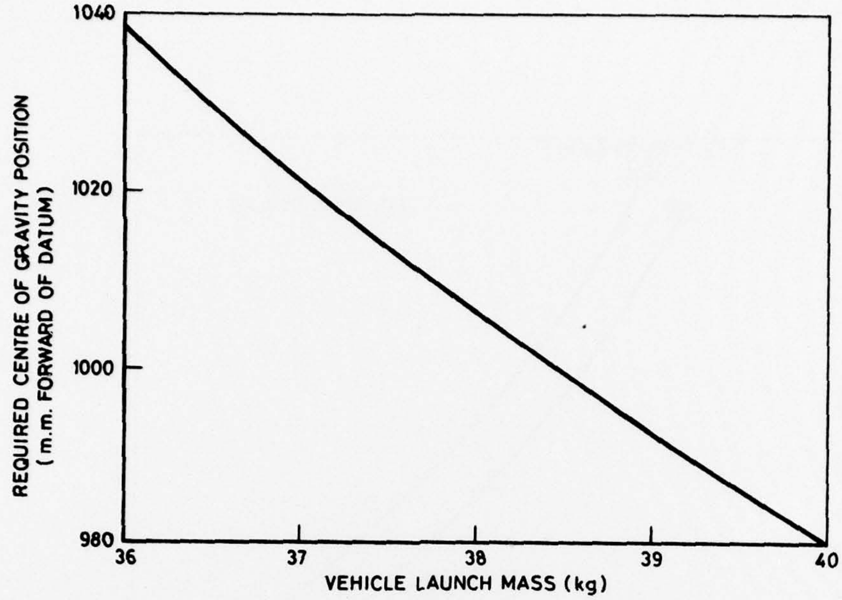

Figure 5. Required vehicle centre of gravity position at maximum Mach number for 10% static margin v vehicle launch mass (initial design configuration)

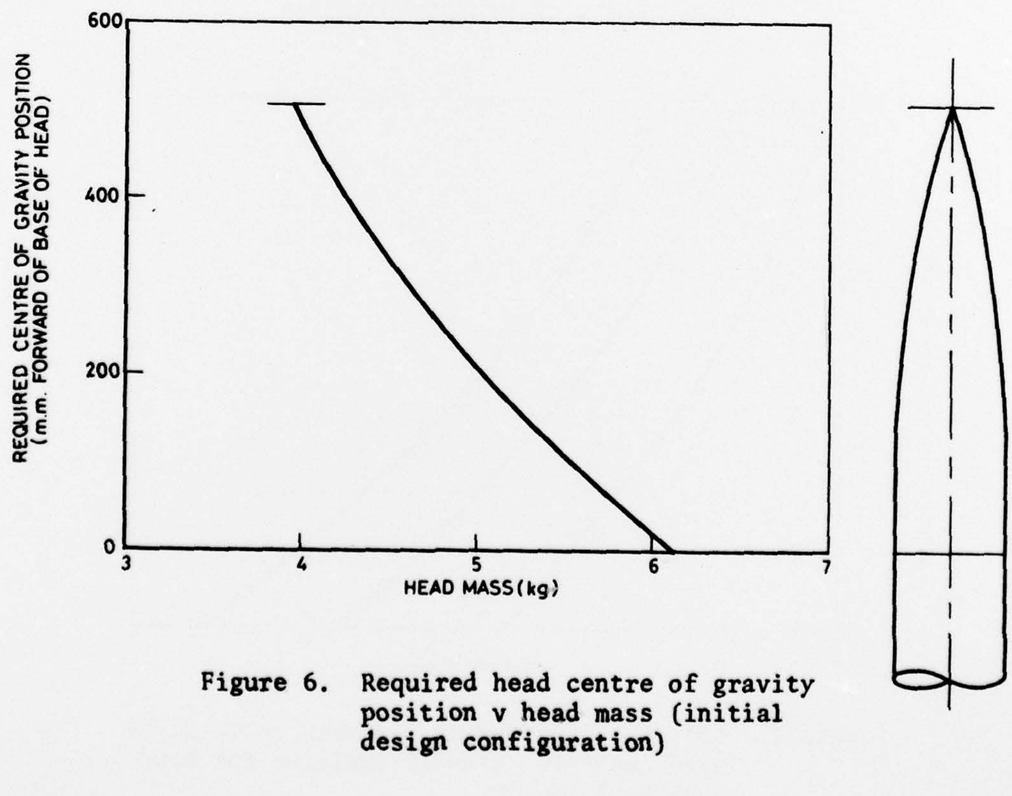

Figure 6. Required head centre of gravity position v head mass (initial design configuration)

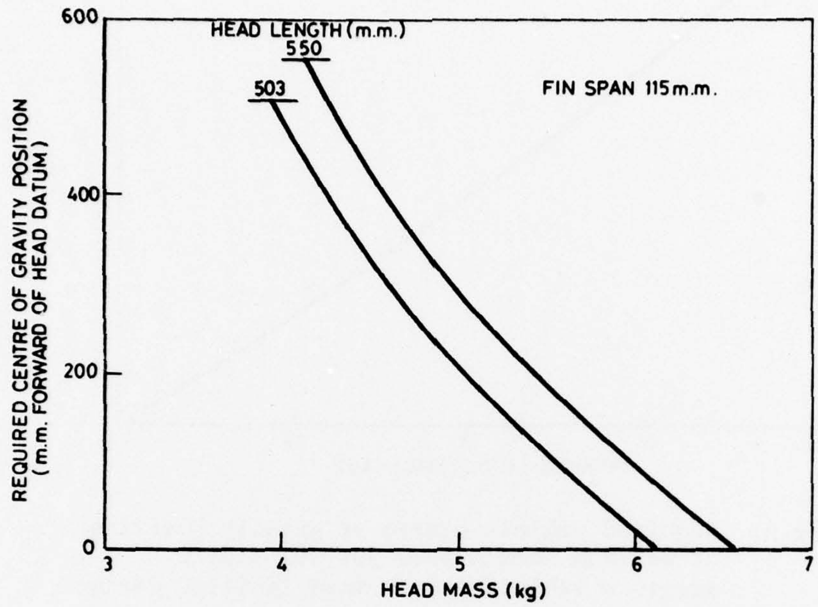

Figure 7. Effect of increasing head length on required head centre of gravity position

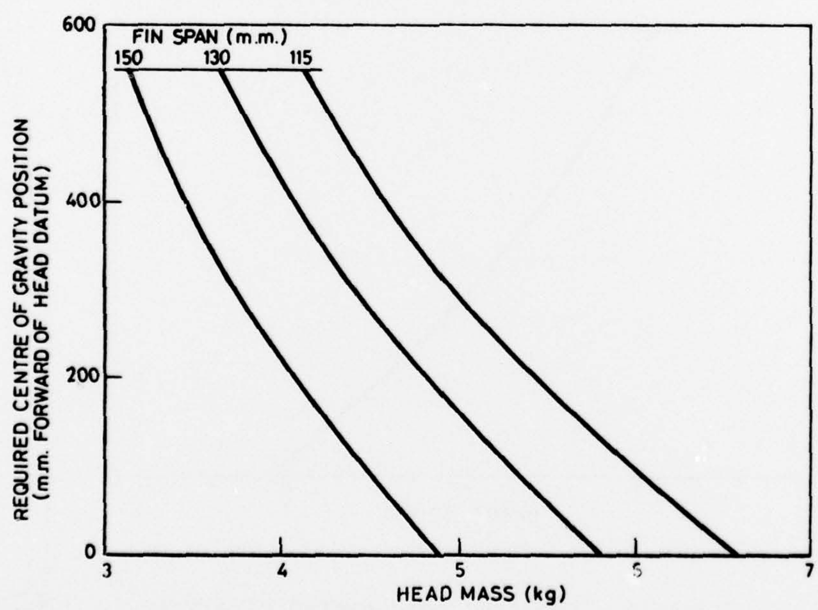

Figure 8. Effect of increasing fin span on required head centre of gravity position for head length of 550 mm

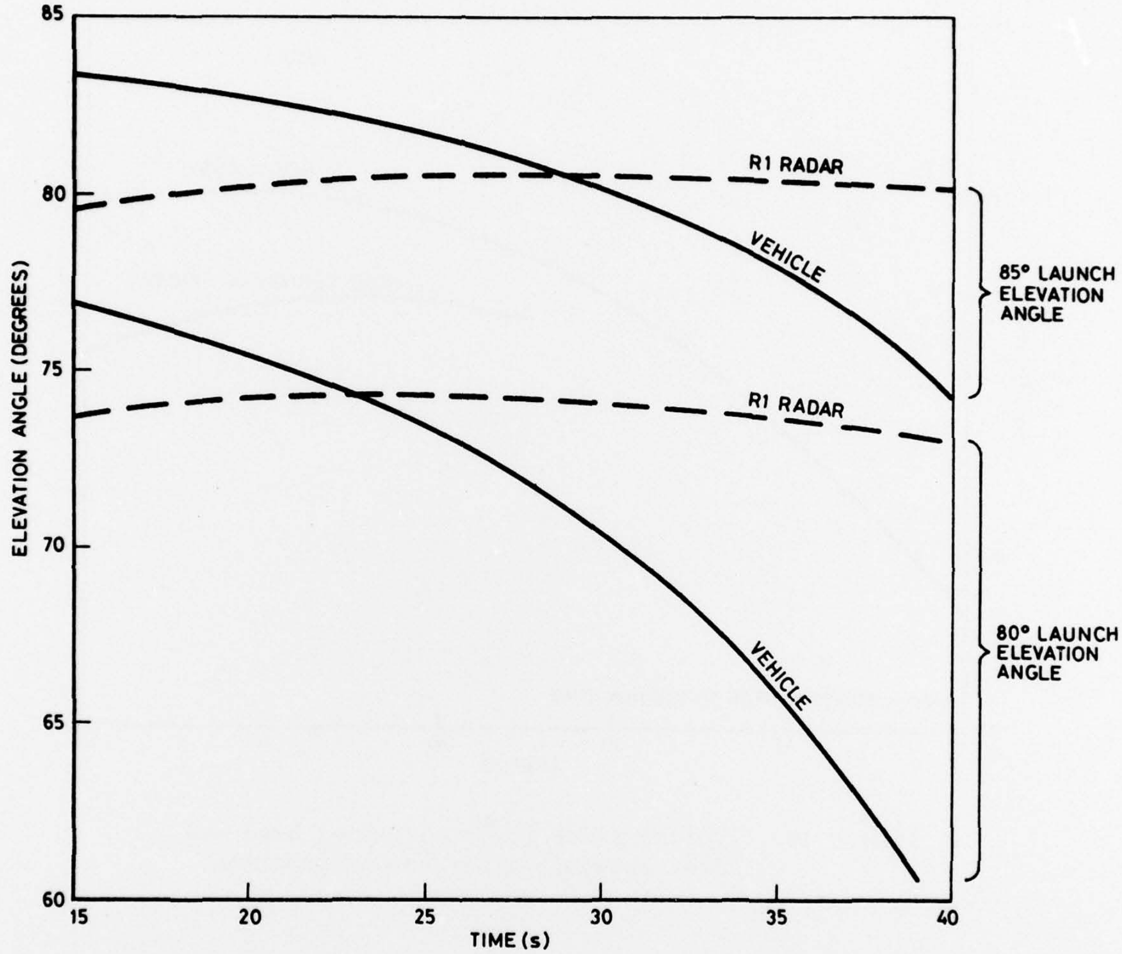

Figure 9. Vehicle flight path elevation angle v R1 radar elevation angle

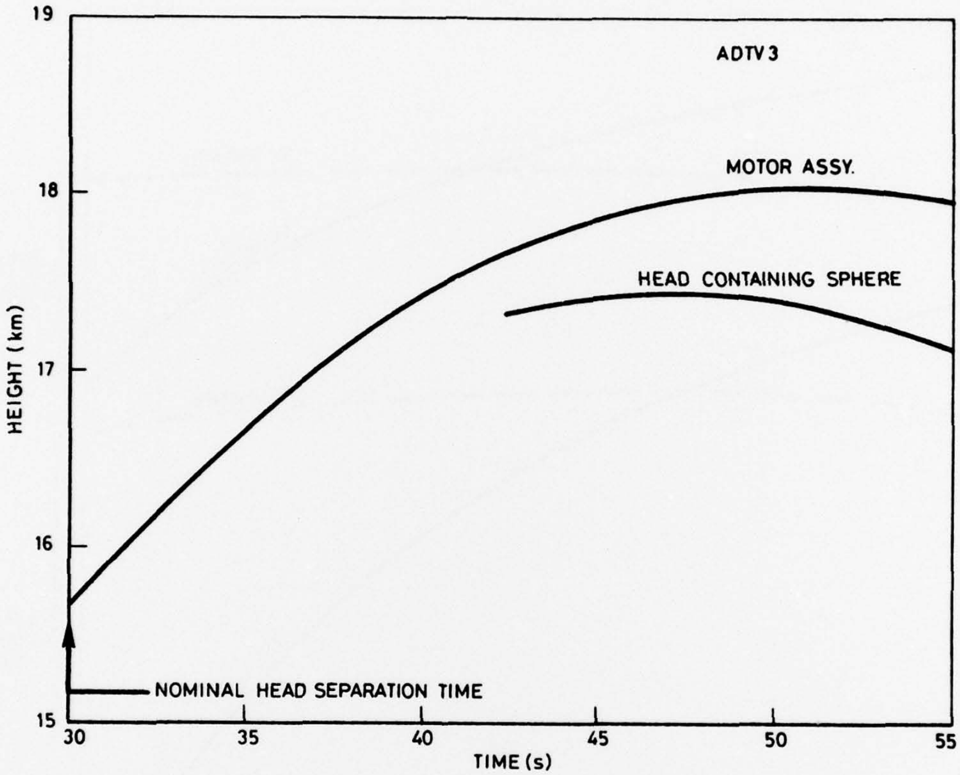

Figure 10. Typical radar trajectories of head and motor assembly after head separation

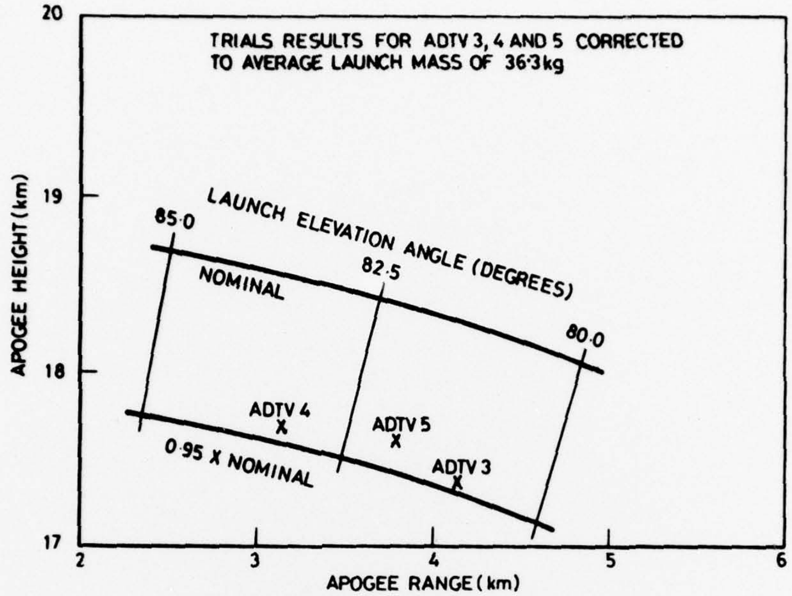

Figure 11. Apogee height and range for a 5 kg head separated from the motor assembly at +30 s

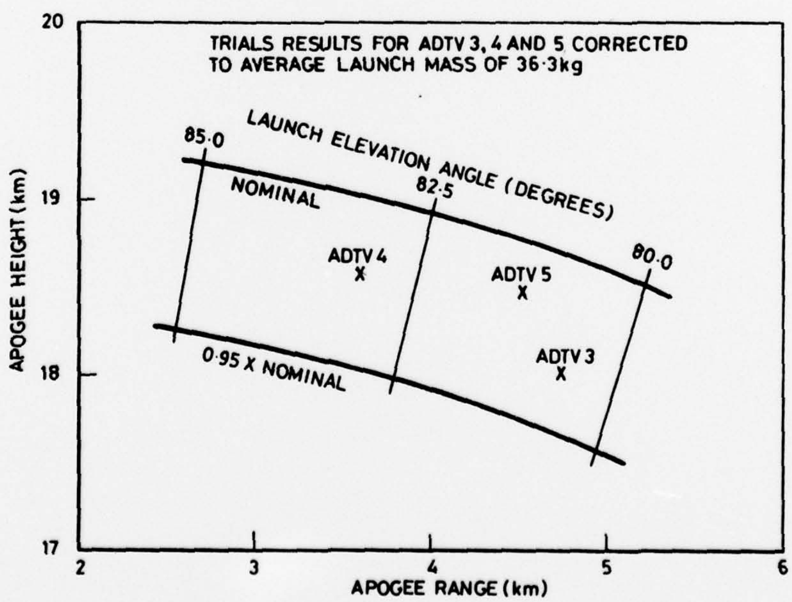

Figure 12. Apogee height and range for the motor assembly - head separation at +30 s

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